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Structure of natural impact glasses on AFM data

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Natural glasses were one of the first mineralogical objects to study by SPM. The main types of natural glasses are *impactites* (as a result of explosive and shock processes in rocks), *tektites* (as a result of ablation and transport of the melted substance over significant distances) and *obsidians* (solidified volcanic melts) [1]. AFM observations of the glasses fracture predominantly show small hillocks, a few tens nanometers wide and about one nanometer high [2-6]. It is tempting to assume that the surface of cleavage in glass fracture reveals the structural heterogeneity. Structural differences due to PT-conditions of cooling, concentration and composition of impurities, contribute to the appearance of nanoscale structural heterogeneity of the glasses. This heterogeneity can be caused both by density fluctuations in pure silicon dioxide, and by composition fluctuations in multicomponent glasses [7]. The aim of this study is to attempt to connect structural and chemical data on natural impactite glasses to the results of AFM observations of their surface.

The objects of our study are natural impact glasses: *irgizite* from Zhamanshin Crater (Kazakhstan) and *Libyan Desert glass* (Egypt), from the rocks of the Rice crater (Germany) and the Kara astroblem (Russia); and *moldavite*, related to tektites (Czech Republic).

The chemical and local structure was determined by the methods of infrared and Raman spectroscopy, the local chemical composition was estimated by X-ray energy-dispersive spectral analysis. Nanoscale topography was detected by the atomic force microscopy.

The surface morphology of the samples has been characterized by AFM measurement in tapping mode using an Integra Prima (NT-MDT, Russia) with super sharp silicon cantilevers of model SSS-NCH (Nanosensors). In the majority of works, the surface roughness is used to quantify objects on AFM images, which is estimated from a standard histogram. In this work we proposed to evaluate the nanoheterogeneity of glasses by the diameter of hillocks.

The dependence of the degree of saturation of the structure of natural glasses with cation-modifiers (Al, Na, Ca, Mg) on the dimensions of inhomogeneities on their surface is revealed. These results allow relating IR spectroscopic and EDS analysis data with nanostructural features of the glasses. This suggests that the factor, mainly determining the nanoheterogeneity of the glasses at the AFM images, is chemical. Cations of modifiers are located in free cavities of the structural lattice, compensating excessive negative charge of the complex anion. The strength of the modifier-oxygen bond is much lower than the strength of the glass-to-oxygen bond, so the modifiers do not form strong coordination groups, and when the glass breaks, the bonds break along the clusters of modifier elements. The presence of impurities, partially framing the nanoscale regions of the glass-forming matrix, promotes the cleavage of the material along the impurity-containing regions and the formation of a rough cleavage surface.

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